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THE TIME OF SOUTHERLY CHANGES AT KELBURN.

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With the intention of ascertaining whether any period of the day favours a change to southerly wind directions at Wellington, the Kelburn anemograms have been subjected to a simple analysis by Dr. Bondy, who prepared frequency tables showing the number of changes at each hour N.Z.M.T. for individual months throughout the decade 1932 - 1941. Any wind change to the southerly quadrant was counted, the occasion being credited to the nearest exact hour. At the same time a sub-group of strong southerlies was examined, for this purpose a "strong" southerly being defined arbitrarily as one which within three hours of the direction change attained a mean velocity of at least 10 miles per hour. The time of the change still refers to the initial wind shift irrespective of the initial speed. All southerly changes not thus classed as "strong" will be described as "weak".

Table Ia sets out the average number of weak and strong changes per month and per year while Table Ib gives equivalent data which show the average interval in days between successive changes. To generalise about 4 weak southerly changes occur monthly as well as 3 to 4 strong changes. In January 1939 there were as many as 12 changes 9 of which were strong and in contrast only 2 changes both of which were weak occurred in February 1932. The annual frequency extremes were as follows:- least in 1932 with only 75 changes including only 28 strong; most in 1939 with 114 changes, 58 being strong; 1940 had most weak changes, viz. 62, besides 41 strong.

There are usually fewest changes in July; fewest strong changes in August, February and July; and fewest weak changes in July and September.

TABLE I.

(a) Average number of southerly changes.

	Jan.	Feb.	Mar.	Apr.	May	June	Jly.	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Weak	4.9	3.9	3.9	3.9	3.7	4.4	2.7	4.3	2.8	3.8	4.7	4.5	47.5
Strong	3.6	2.7	4.1	3.5	3.7	3.9	3.0	2.8	3.6	4.5	3.6	3.4	42.4
Total	8.5	6.6	8.0	7.4	7.4	8.3	5.7	7.1	6.4	8.3	8.3	7.9	89.9

(b) Average interval in days between southerly changes.

	Jan.	Feb.	Mar.	Apr.	May	June	Jly.	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
Weak	6.3	7.3	7.9	7.7	8.4	6.8	11.5	7.2	10.7	8.2	6.4	6.9	7.7
Strong	8.6	10.5	7.6	8.6	8.4	7.7	10.3	11.1	8.3	6.9	8.3	9.1	8.6
Total	3.6	4.3	3.9	4.1	4.2	3.6	5.4	4.4	4.7	3.7	3.6	3.9	4.1

See also figure 1.

Table IIa shows the frequency of occasions during the ten years considered when southerly winds set in during the three hourly intervals centred at midnight, 3 a.m. etc., the information being divided seasonably and according to the two grades of wind strength. The diurnal variation of these frequencies is perhaps better illustrated in the alternative Table IIb wherein the frequencies are expressed as percentage deviations from the mean of the season or class.

TABLE II.

(a) Number of southerly changes arriving within 3-hourly periods centred at the following hours (totals for 1932-1941).

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TABLE II (Continued)

	Season.	00	03	06	09	12	15	18	21	Total
Weak	Spring	12	17	18	18	16	11	12	9	113
	Summer	16	16	17	17	26	16	14	11	133
	Autumn	12	16	11	22	20	9	16	9	115
	Winter	9	7	13	12	28	23	14	8	114
	Year.	49	56	59	69	90	59	56	37	475
Strong	Spring	12	11	18	13	18	18	16	11	117
	Summer	9	5	16	18	13	7	18	11	97
	Autumn	15	13	14	18	15	11	10	17	113
	Winter	12	12	5	14	14	13	13	14	97
	Year	48	41	53	63	60	49	57	53	424
All	Spring	24	28	36	31	34	29	28	20	230
	Summer	25	21	33	35	39	23	32	22	230
	Autumn	27	29	25	40	35	20	26	26	228
	Winter	21	19	18	26	42	36	27	22	211
	Year	97	97	112	132	150	108	113	90	899

(b) Diurnal variation of frequency of southerly changes expressed as percentage deviations from the means.

Weak	Spring	-2	+2½	+3½	+3½	+2	-3	-2	-4½
	Summer	-0½	-0½	0	0	+7	0	-2	-4
	Autumn	-2	+1½	-3	+7	+5	-5	+1½	-5
	Winter	-5	-6	-1	-2	+12	+8	0	-6
	Year	-2	-1	0	+2	+6½	+0	-1	-4½
Strong	Spring	-2½	-3	+3	-1½	+3	+3	+1	-3
	Summer	-3	-7½	+4	+6	+1	-5½	+6	-1
	Autumn	+0½	-1	0	+3½	±0½	-2½	-3½	+2½
	Winter	0	-0½	-7½	+2	+2	+1	+1	+2
	Year	-1	-3	0	+2	+2	-1	+1	0
All	Spring	-2	-0½	+3	+1	+2½	0	-0½	-3½
	Summer	-1½	-3½	+2	+2½	+4½	-2½	+1½	-3
	Autumn	-0½	0	-1½	+5	+3	-4	-1	-1
	Winter	-2½	-3½	-4	0	+7½	+4½	+0	-2
	Year	-1½	-1½	0	+2	+4	-0½	0	-2½

Table III gives the diurnal variation averaged over the whole period for each of the 24 hours but the figures have been smoothed slightly by the formula

~~$a'_n = \frac{a_{n-1} + a_n + a_{n+1}}{3}$~~, $a'_n = \frac{a_{n-1} + a_n + a_{n+1}}{3}$

Where the a_n represent the unsmoothed series of hourly values. The smoothed hourly values have been expressed as departures from one twentyfourth of the total

Figure 2 gives graphical representations of these variations.

TABLE III.

Frequency of time of arrival of southerly changes. Number of changes in ten years expressed as departures from the average. (Data have been smoothed slightly.)

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total/24
Weak	-4	-2	-3	-1	+2	+1	0	-3	+2	+3	+5	+3	+10	+8	+7	0	-1	+1	-1	0	-4	-7	-9	-5	19.8
Strong	-2	-1	0	-4	-2	+1	0	-1	0	+3	+7	+5	+2	-2	-2	-1	+1	+1	+2	0	+4	0	-3	-8	17.7
All	-5	-3	-3	-5	-1	+2	0	-3	+1	+7	+12	+8	+12	+7	+4	-2	-4	0	0	0	0	-7	-12	-13	37.5

t becomes apparent that there is a definite tendency for weak outherlies to come in during the period 8 a.m. to 3 p.m., noon being the most favoured hour. This suggests that sea-breeze affects play a prominent part in producing such changes. When treated seasonally weak changes show decreasing diurnal variation of frequency in the order - Winter, Autumn, Summer, Spring. In Summer, however, the mid-day peak is very sharp and there are more light southerly changes than in the other seasons.

The large Winter variation is the most remarkable feature of this set of data. The hour of maximum frequency is approximately: Spring - 8 a.m.; Summer - 12 a.m.; Autumn - 9 a.m.; Winter - 1 p.m.

The date for the strong changes are more irregular. On the average the chief features are a maximum about 10 a.m., a secondary maximum at 8 p.m. and a minimum at 11 p.m. Summer is the season showing the greatest daily variation with maxima about 9 a.m. and 6 p.m. and minima about 3 a.m. and 3 p.m. Whether this double fluctuation is a real effect or not is not clear. However, the chief maximum in the forenoon suggests that the sea breeze affects in their full Summer development produce a noticeable influence upon even the stronger southerlies. One other pronounced feature is worth mentioning, namely the minimum occurring about 6 a.m. in Winter.

~~(a) This is illustrated graphically in figure 1.~~

~~(b) Figure 2 gives graphical representations of these variations.~~

The comparative shortness of the period of the data makes a detailed discussion of the seasonal effects upon the diurnal frequency variation inadvisable. It would appear that the regular diurnal barometric fluctuations are not directly concerned. The most promising field for conjectures concerns stability, it is possible that the increased turbulence over the land during the day or the formation of low level inversions at night may have an appreciable influence.

<u>Description of a mid-day wind change.</u>

The case of Saturday, 8th August 1942 has been examined as an example of a mid-day change at Wellington. The pressure gradient at the time was southwesterly with an anticyclone to the northwest. During the Friday the surface winds backed from southerly to northwesterly and freshened temporarily during the afternoon. By 2300 hours there was only a very light WNW breeze which became still weaker after 0400 hours on Saturday, there being only isolated puffs shown on the anemometer with completely calm intervals. At 1000 hours very light ESE airs commenced, changing at 1210 to SSE and increasing in force. The directions were rather variable and went to SW at 1245 by which time a moderate wind was blowing. A further veering to W at 1300 was followed by a backing to the south at 1400, the breeze persisting with intermittent gusts to 20 m.p.h., or more, until late evening.

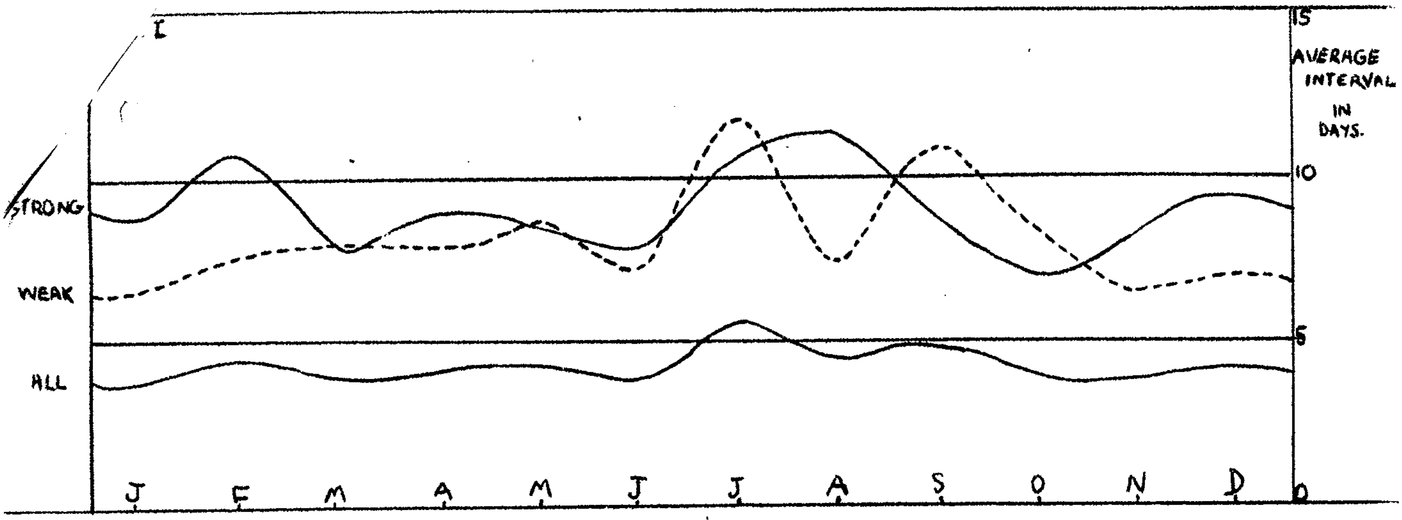
Friday night was clear and frosty in central New Zealand and from 0800 on Saturday onward there was a smoke haze over Wellington, the top of the haze being noted from Kelburn to rise during the morning from 800 feet to 1200 feet. This latter height agreed with the report from the Union Airways plane from Palmerston North in the middle of the morning. From the upper air temperatures it would appear that the change came soon after the ground had reached the representative temperature.

The Kelburn pilot balloon at 0400 indicated a slight westerly drift up to 4,000 feet but by 0800 there were northeasterly airs up to 1300 feet with light northwesterlies above until the southwesterlies came in at 3,500 feet. The 1010 balloon gave the limit of the northeasterlies as 1,000 feet with northwesterlies up to 2,500 feet. In the afternoon there were southeasterlies below tending southwesterly with height.

It may be noted that there was no air mass change there being a steady rise in dew point (after the frost) from 36° F to 44° F at 1400 and thereafter, a slow decrease, the variations, showing no appreciable discontinuity as a result of the wind change, were consistent with normal diurnal affect.

(P.T.O.)

It would appear that the cessation of the cold drainage off the high land and the burning off of the temperature inversion were major factors upon the time of the wind change. Following the change convective instability increased as shown by the sudden appearence of cumulus cloud, of which the development become sufficient late in the evening to produce a shower. Mention should be made of the fact that South Island stations had light westerly winds changing to southwesterly during the morning. For instance, at Cape Campbell the wind backed from Wl to southerly at 1050 which was 80 minutes before the change at Kelburn, a time interval too short considering the wind speeds concerned for the change to have advanced across Cook Strait as a definite wind shift line. Nevertheless some sort of squall time must have developed within the Straits region as a line of towering comulus was observed offshore from Wellington prior to the changes.


I
STRONG
WEAK
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J F M A M J J A S O N D
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AVERAGE INTERVAL IN DAYS.
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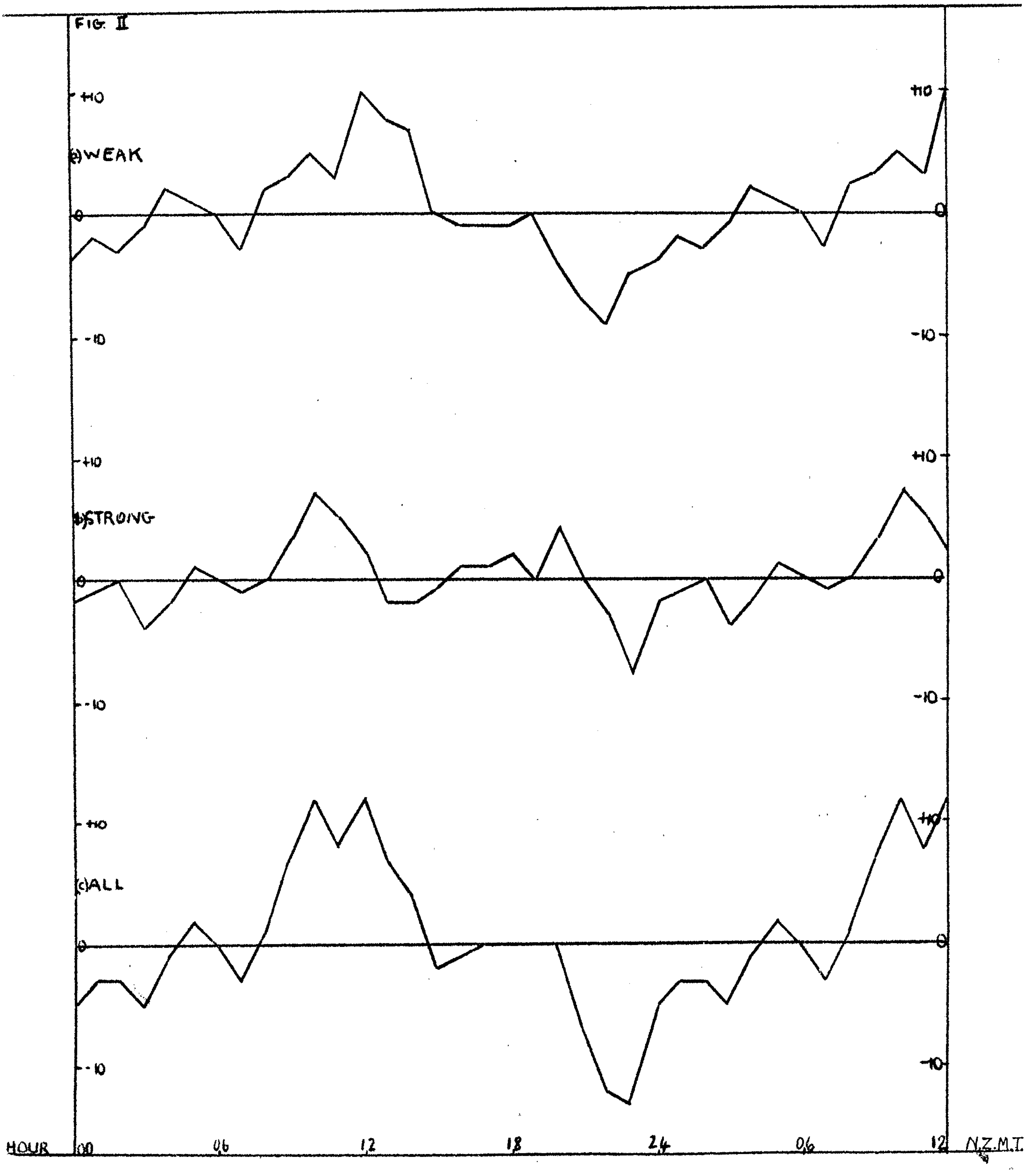
FIG. II
+10
(a) WEAK
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-10
+10
(b) STRONG
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(c) ALL
0
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HOUR
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N.Z.M.T.